For example, according to one theorem, if (1) the source/sink pair is not inline, (2) the pair is separated by a distance that is a multiple of four, (3) the time of departure for one color is a multiple of four, (0, 4, 8,...), and (4) that of the other color is the same but staggered by two, (2, 6, 10,...), then all conflicts are resolvable by local one-one negotiation. Consequently, the pattern in the figure is solvable without central control. On the other hand, several resolvable configurations that require central control have also been found. The objective of the work on this cellular model of air traffic management is to complete the theory for the two-color case, and then extend the results to more colors.

Point of Contact: G. Meyer
(650) 604-5750
gmeyer@mail.arc.nasa.gov

Inflight Activity Breaks Reduce Sleepiness in Pilots

David Neri, Melissa Mallis

Flight operations often result in fatigue, sleep loss, and circadian disruption leading to significant decrements in alertness and performance. These problems can be difficult to detect reliably and to counteract effectively in constrained operational environments such as the flight deck. Left unaddressed, alertness and performance decrements reduce the margin of safety and increase the chances of an incident or accident. One serious challenge facing flight crews is the requirement to maintain vigilance during long, highly automated, and often-uneventful nighttime flights.

Currently there is no system in place to assist flight crews in managing their alertness. Furthermore, strategy choices are severely restricted in the flight deck environment. For example, although previous research has demonstrated the effectiveness of a 26-minute nap in significantly improving subsequent physiological alertness and performance, the FAA does not currently sanction napping on the flight deck. Current Federal Aviation Regulations also mandate that flight crews remain seated ("...each required flight crewmember on flight deck duty must remain at the assigned duty station with seat belt fastened while the aircraft is taking off or landing, and while it is enroute") with but a few exceptions.

Nevertheless, surveys of flight crews reveal that many use physical activity as a countermeasure during fatiguing flights. Despite this widespread belief by flight crews in the effectiveness of physical activity, there have been no controlled studies of its effect on vigilance, sleepiness, and performance in the aviation environment. This flight simulator study examined whether regularly spaced brief bouts of controlled physical activity (standing up, walking, stretching) combined with social interaction could improve alertness and performance during a long, uneventful, overnight flight requiring extended wakefulness and vigilance. The data obtained from this study support NASA's Aero-Space Technology Enterprise and its objective of reducing the aircraft accident rate.

Fourteen two-man crews flew a 6-hour (2:00-8:00 a.m.) uneventful flight from Seattle to Honolulu in the Ames 747-400 flight simulator. The 14 subjects in the Treatment Group received five short (7-minute) breaks with controlled physical activity and social interaction, spaced hourly during the cruise portion of the flight. An equivalent number in the Control Group received only one 7-minute break in the middle of cruise. Measures of psychomotor vigilance performance, subjective sleepiness, continuous brain wave activity (electroencephalography; EEG), and continuous eye movement activity (electrooculography; EOG) were collected throughout the flight.

Treatment subjects receiving the hourly activity breaks reported significantly greater subjective alertness when it was measured at 5, 15, and 25 minutes post-break, with the strongest effects near the time of the daily circadian trough in alertness (~5:00-6:30 a.m.). The benefit in subjective alertness dissipated by 40 minutes post-break, and there was no evidence of objective vigilance performance improvement when it was sampled from 15 to 25 minutes post-break. There was the expected performance deterioration in both groups because of an elevated sleep drive and the circadian time of day. However, during the latter part of the night, the EEG and EOG measures for the Treatment Group revealed statistically significant post-break reductions relative to the Control Group in slow eye movements, EEG theta-band activity (two indicators of drowsiness), and episodes of stage 2 and 3 sleep. The figure shows that in the sampled 15-minute periods at 5:40 a.m. and 6:40 a.m., the Control Group pilots were either asleep (stage 2 or 3) or exhibiting significant sleepiness (EEG theta activity) 20%–25% of the time. Conversely, the Treatment Group pilots, who had just received a 7-minute break, fell asleep or exhibited significant sleepiness for less than 5% of the time during the same two periods. Furthermore, higher numbers of Control subjects exhibited sleepy behaviors during these two time periods (12 of 14 subjects) than Treatment subjects (no more than 7 of 13 subjects).

Overall, the physiological data were consistent with subjective reports in indicating that brief, controlled activity breaks were effective in reducing nighttime sleepiness for at least 15 minutes post-break. The breaks provided particular benefits during the early morning hours—the circadian time associated with the greatest vulnerability to fatigue. Furthermore, the breaks continued to mask any underlying sleepiness for up to 25 minutes post-break. The physical activity that occurred as part of the breaks most likely produced enough sympathetic nervous system activation to produce an EEG response characteristic of increased arousal.

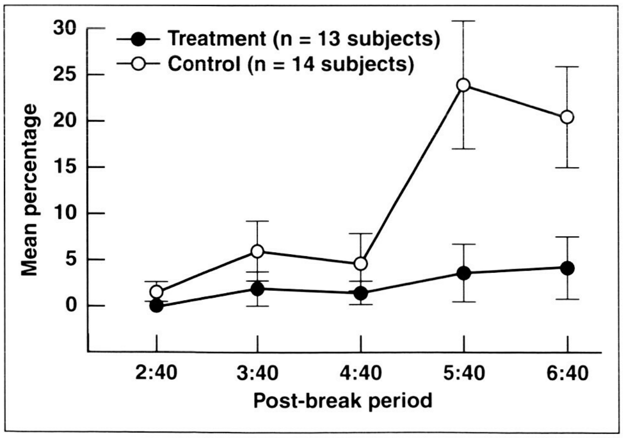

Fig. 1. Mean percentage (±1 s.e.m.) of combined EEG theta activity and stage 2 or 3 sleep exhibited by pilots on the flight deck during the 15-minute period following a controlled activity break (Treatment Group) or during a corresponding time period (Control Group). The Control Group received only the middle break (ending at 4:40 a.m.).

Controlled activity breaks are not substitutes for adequate sleep, but they do represent a practical, short-term countermeasure to the fatiguing effects of a long nighttime flight, provided appropriate controls are in place to ensure the wakefulness and alertness of the other crewmembers remaining on the flight deck.

Point of Contact: M. Mallis
(650) 604-3654
mmallis@mail.arc.nasa.gov

Communication Strategies for Correcting Errors

J. Orasanu, U. Fischer, C. Van Aken, L. McDonnell

Maintaining safety in high-risk engineered environments like aviation is a team effort that depends crucially on the team members' efficiency in monitoring each other's performance and on their effectiveness in intervening if they consider a decision or action to be unsafe. Unfortunately, analyses of aviation accidents and incidents indicate that pilots, in particular junior pilots, have frequently failed in this important crew function, especially in situations in which their interventions posed a direct challenge to the other crewmember's judgment and decision-making skill. In such situations, junior crewmembers will sometimes only hint at the possibility of a problem rather than tell the captain explicitly to perform a corrective action.

This kind of communication failure has been identified as a "monitoring/challenging error" by the National Transportation Safety Board (NTSB) and was found to occur in over 75 percent of the accidents reviewed. Moreover, monitoring/challenging failures appear to contribute to "plan continuation errors." These are errors in which the crew continues with its planned course of action in the face of cues suggesting that the plan should be reconsidered. The research reported here is an effort to understand communication strategies for correcting crew errors, and looks at differences in strategies as a function of crew position (captain vs. first officer) and of risk and face-threat posed by the problem.